NAVAL UNDERWATER SYSTEMS CENTER

(16) F11552

(17) SF11552001

(6) BROAD BAND/MILS LISTENING SYSTEM.

by

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(14) NUSC/NL-TM

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INTRODUCTION

The New London Laboratory of the Naval Underwater Systems Center (NUSC/NL) and the Air Force Eastern Test Range (AFETR), at Patrick Air Force Base, Florida, have jointly funded the design, fabrication and installation of a Broad Band/MILS Listening System off the south coast of Bermuda. The effort is for an acoustic receiver for missile impact location and splashdown on the ocean surface and for detection of underwater explosions via the SOFAR channel. The system also is an acoustic research tool for the Naval Underwater Systems Center.

END ABSTRACT

DISCUSSION

The Broad Band Listening System is implanted approximately six nautical miles south of Bermuda at a geographic location of 32° 08' 41" N and 64° 50' 43" W, ~~is~~ was positioned by a Decca Hi-Fix Navigational System. An acoustic

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ADMINISTRATIVE INFORMATION

This memorandum was prepared under NUSC/NL Project Title: Underwater Sound Propagation ~~Studies~~, W. Thorp and W. Schumacher, Principal Investigators. The Sponsoring Activity was NAVSHIPS 00V1, J. Reeves, Program Manager.

[redacted]

transponder was also attached to the anchor cable for acoustic location at a later time. The system consists of two assemblies (upper and lower). The upper assembly is buoyed 3,050 feet above the ocean floor at a depth of 4,030 feet. The lower assembly is at a water depth of 4,530 feet. Each assembly consists of two hydrophones, one temperature sensor, one current speed sensor, one current direction sensor, one electronic package and one pressure housing. An assembly as viewed before pressure testing is shown in Figure 1. The assemblies provide acoustic receivers in the SOFAR channel for long range propagation studies. They also provide for a Missile Impact Location System (MILS) at Bermuda. Other useful applications are ambient noise studies, attenuation measurements, bottom loss studies and biological and shipping noise. The environmental sensors provide a means of long term correlation studies of temperature and current variations with acoustic propagation phenomena.

SYSTEM DESCRIPTION

The assemblies have 3,050 feet of 4-conductor riser cable, seven nautical miles of 4-conductor sea cable (Dalton) and a splice to the final 4-conductor sea cable to the Naval Underwater System Center's Tudor Hill Laboratory. The electrical connections of the assemblies are made through D. G. O'Brien double "O" ring protected connectors. The assemblies were temperature and pressure tested (to 2,000 psi) prior to implantment.

The acoustic receivers, as shown singularly in Figure 2, were made by NUS Corporation of Paramus, New Jersey. They are the High Reliability Deep Sea Hydrophones Model 1125. These hydrophones have a life expectancy of five years with less than ±0.5 db change in sensitivity for a two year period. The sensitive element is made of lead-metaniobate and its calibration is traceable to the bureau of standards. The hydrophone has a flat (±1.0 db) and omnidirectional frequency response from 10 Hz to 5 KHz and is useable to 10 KHz as depicted in Figures 3 through 6. The self-contained preamplifier has a fixed gain of 20 db and self noise characteristics such that detection of zero sea state is possible to frequencies of 5 KHz. An internal 10-Ω precision resistor permits an in-situ calibration feature. The hydrophone case is made of a titanium alloy for maximum resistance to salt water corrosion. The active element is double rubber booted for minimization of salt water migration. The space between the boots is oil filled and contains a metal shield for strength and reduction of pickup from extraneous fields. The output of the preamplifier feeds a low output impedance cable driver. The pressure case is attached to the associated 4-conductor FSS-2 cable through a neoprene mold.

The temperature probe, shown in Figure 7, is made by Gulton Industries, and is a Model MET-2. The probe is basically a two wire device for

measuring liquid temperatures over the range of -5° C to + 40° C to an accuracy of 0.025° C. The sensor consists of piezoelectric elements which cause a change in their natural resonant frequency when the temperature of the element itself changes. The output signal is a constant amplitude varying frequency signal directly proportional to the temperature. The probe contains a water-tight Marsh and Marine connector type XSG-2-BCL. The DC power and AC signal are on the same wire so that decoupling between the power supply and signal is required. The unit has an antifoulant shield constructed of a glass based epoxy, which inhibits adherence of sea life to the sensing surfaces. The thermal time constant of the unit is typically fifteen seconds. The output frequency varies over the range of 10KC to 75KC yielding a sensitivity of nominally 1KHz/°C. The calibration data for both temperature sensors is shown in Table 1, sheets 1 through 6 inclusive. The resolution is 0.001°C for a one second gate time and may be increased tenfold by using a ten second gate time. It should be noted that interpolation between data points can be utilized, but the accuracy limit should be borne in mind.

The underwater speed sensor, Model 460, shown in Figure 8, is made by Hydro Products. The unit is a precision balanced, high impact polystyrene Savonius rotor mounted on carbide self-cleaning bearings. All metal parts are made of 304 stainless steel for maximum resistance to the corrosive ocean environment. The operation of the unit is as follows: water movement past the underwater sensor rotates the Savonius rotor at an angular rate proportional to the speed of the water flow. There are ten magnets imbedded into the polystyrene and a magnetic reed switch mounted in the vicinity for sensing. The output signal is therefore ten closures per revolution. A calibration curve for both units is shown in Figure 8A. The curve represents sensor speed in knots as a function of rotor output in magnetic switch closures per second.

The current direction sensor is also made by Hydro Products. It is their Model 465-A and is shown in Figure 9. The sensor consists of a balanced free-swinging plastic vane which is magnetically coupled to a micro-torque potentiometer and compass assembly located in the housing. All metal parts, with the exception of the main housing of brass, are made from 304 stainless steel. The static error has been reduced by giving special consideration to internal bearing design to minimize compass and potentiometer loading. The sensor is oil-filled and pressure equalized so that operation at any depth is possible. The linear potentiometer is referenced to a viscous damped, magnetic compass rather than to the case. As a result, directions indicated are relative to magnetic north irrespective of the sensor orientation. The sensor has a linearity of $\pm0.35^{\circ}$, calibration accuracy of $\pm5^{\circ}$ and a useful range of 353°. The electrical penetrators are male bulkhead connectors which are

in turn, molded into a jumper cable to the D. G. O'Brien connector on the pressure case.

The pressure case shown in Figure 10 contains all the electronic components necessary for switching, balanced operation and calibration of the system. The pressure housing is made of 316 stainless steel and was designed to withstand 7,500 psi. The case contains four bulkhead connectors, D. G. O'Brien type, with two located in each end cap. One end cap receives the two hydrophone input cables while the other contains the sensor cable and the output connection. The pressure case has both radial and facial "O" ring seals for maximum protection from the ocean environment. The housing also has two ounce desiccant bags and was filled with nitrogen before sealing to prevent the formation of condensation on the walls and electric components. The electronic components are shown in Figure 11. The components are mounted on phenolic wafers and contain the calibration oscillators, decoupling circuits, switching components, transformer for balanced operation, voltage controlled oscillator and power supply regulators. The hydrophone cables are coupled to the electronics and built in redundancy is used in the event a failure should occur to one hydrophone unit. The current direction sensor is supplied with a regulated 4.7 VDC across its potentiometer. The swinger is coupled to a VCO in IRIG Band 13. IRIG Band 13 has a center frequency of 14.5 KHz and a bandwidth of 2176 Hz. The output signal from the VCO is a constant amplitude varying frequency signal, proportional to the current direction. A calibration curve is shown in Figure 12. The current direction signal is coupled to the current speed sensor output to the transformer for transmittal to the shore facility at Tudor Hill Laboratory. Since the output signal for the direction sensor is fed through the speed sensor circuit, the result is that we have an amplitude and frequency modulated signal. The frequency of the amplitude modulation is proportional to the current speed while the carrier frequency itself contains the direction information. There are five discrete frequency oscillators in the electronics package at 300, 750, 1500, 3000 and 6000 Hz, respectively. The amplitude of each oscillator is preset at 4.2 millivolts. The signals are linearly mixed and coupled to the 10 ohm calibration resistor for system response curves. The temperature has its decoupling circuits and the output signal coupling network in the electronics package. An electrical schematic is shown in Figure 13.

SYSTEM OPERATION

Each assembly has its own power supplies and control panel for independent operation. Since the operation of both assemblies is identical, only one will be discussed. Each assembly has its own cable pair in the quad sea cable. There are two modes of operation.

How?

Yes OK if one knows the open ckt response of the hydrophone & the transfer function for the cable w/ the load on

<u>Mode 1</u>. Mode 1 selects one hydrophone unit only. Application of 30 volts at 10 milliamps turns the unit on. This mode would lend itself to ambient noise measurements and propagation measurements, since no filtering is needed at the shore facility. The calibration power (57 volts at 50 milliamps) may be applied to plot a system response curve. This curve is dependent upon the termination used but an absolute calibration is possible for any load. The calibration levels preset to 4.2 millivolts and the open circuit crystal response curves enable one to generate a terminal sensitivity curve in the standard manner. The control panels contain all the decoupling and balancing components for effective system operation.

<u>Mode 2</u>. Selection of mode 2 will energize a redundant hydrophone, the temperature sensor, and the current speed and direction sensors. The power requirement for these units is 82 volts at 90 milliamps. The hydrophone signal may be separated from the environmental sensors by amplification and suitable low pass filtering. The temperature sensor signal is separated by high pass filtering, while band pass filtering and amplification is used to recover the current sensor data. A calibration feature is also selectable in this mode and operates exactly as mentioned previously. Listed in Table II are the serial number, manufacturer and system mode for all sensors in each assembly.

CONCLUSIONS

The requirement for a deep sea listening system has been met. In addition, environmental sensors have been provided for long term correlation studies with acoustic information. The built in redundancy and high reliability components should provide a long term acoustical listening system for future experiments in the SOFAR Channel, MILS and propagation runs.

ACKNOWLEDGMENT

The author is grateful for the assistance and cooperation provided by T. Cummings and his associates for successful implantment and splicing requirements. Thanks are also extended to R. Smith for system development and design checking and C. Doherty for testing and evaluation.

L. F. Di Rienzo

L. F. DIRIENZO

Fig. 1

NUSL/NL Tech Memo No. 2212-23-71

Official Photograph

NUSC, New London Laboratory
NP24 - 40146 - 1 - 71

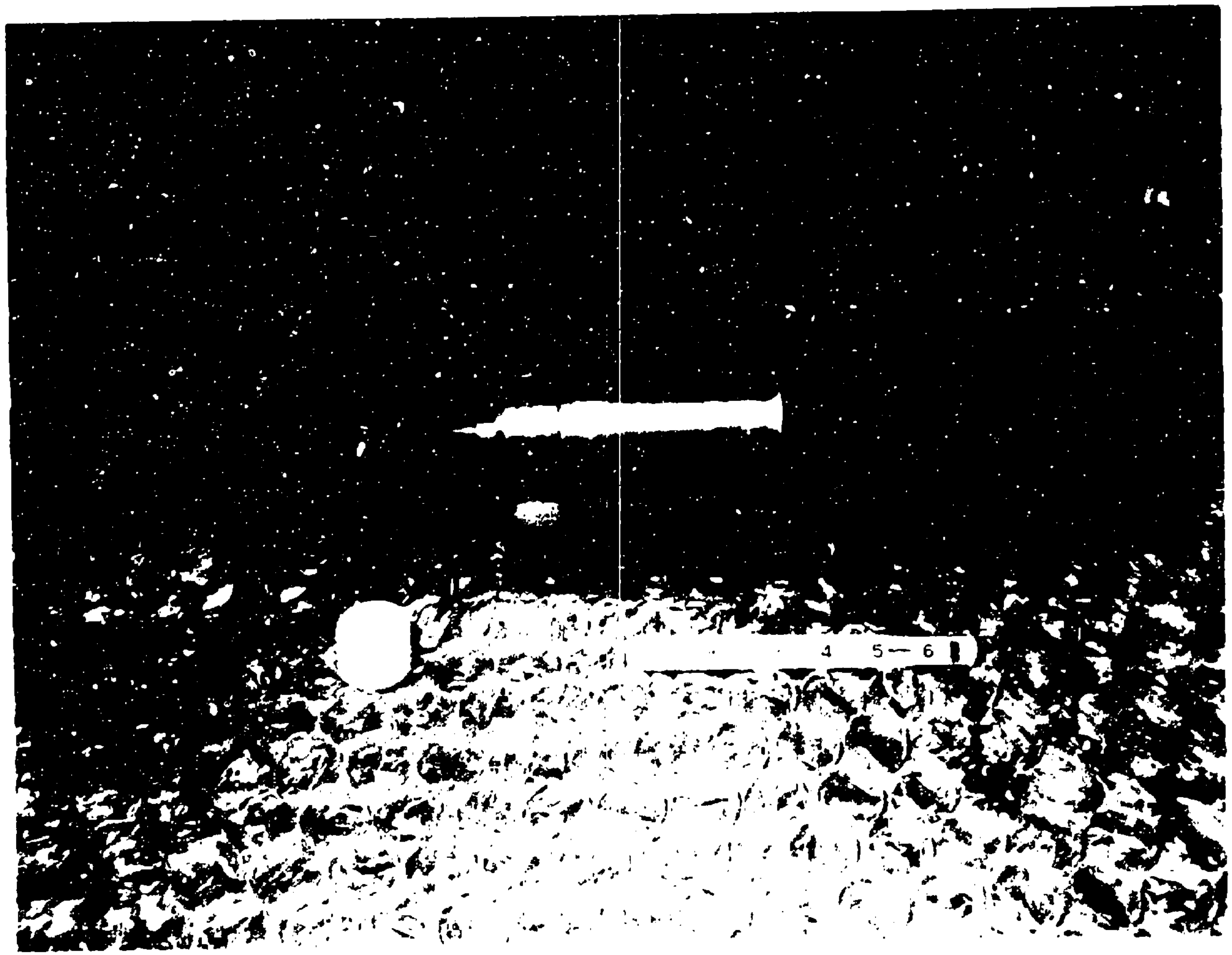


Fig. 2

NUSC/NL Tech Memo No. 2212-23-71

Official Photograph

NUSC, New London Laboratory
NP24 - 40257 - 1 - 71

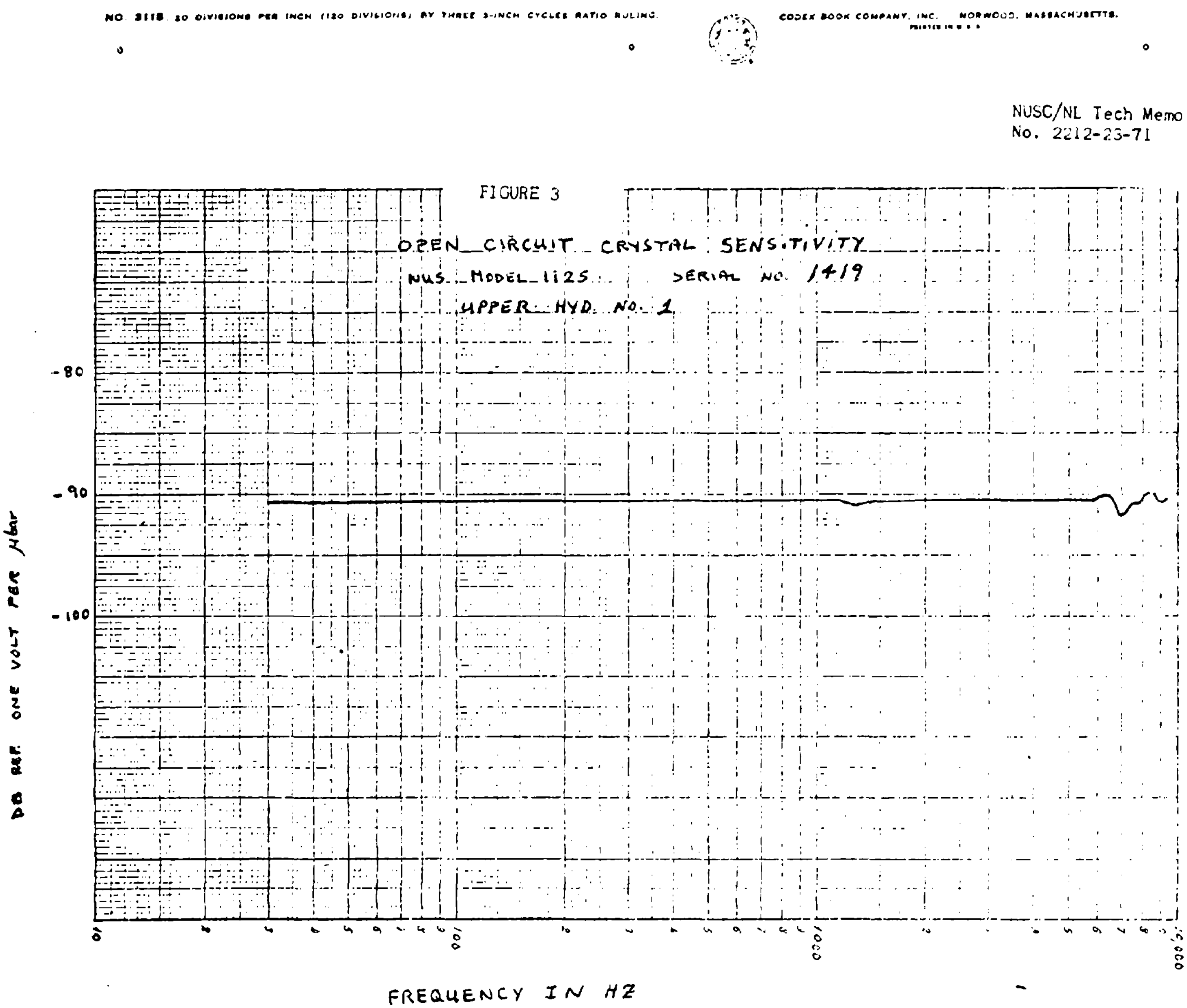

NO. 3118. 20 DIVISIONS PER INCH (120 DIVISIONS) BY THREE 3-INCH CYCLES RATIO RULING.
CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS.
FIGURE 3
OPEN CIRCUIT CRYSTAL SENSITIVITY
NUS MODEL 1125 SERIAL NO. 1419
UPPER HYD. NO. 1
-80
-90
-100
DB REF. ONE VOLT PER μbar
10
100
1000
10,000
FREQUENCY IN HZ

FIGURE 4

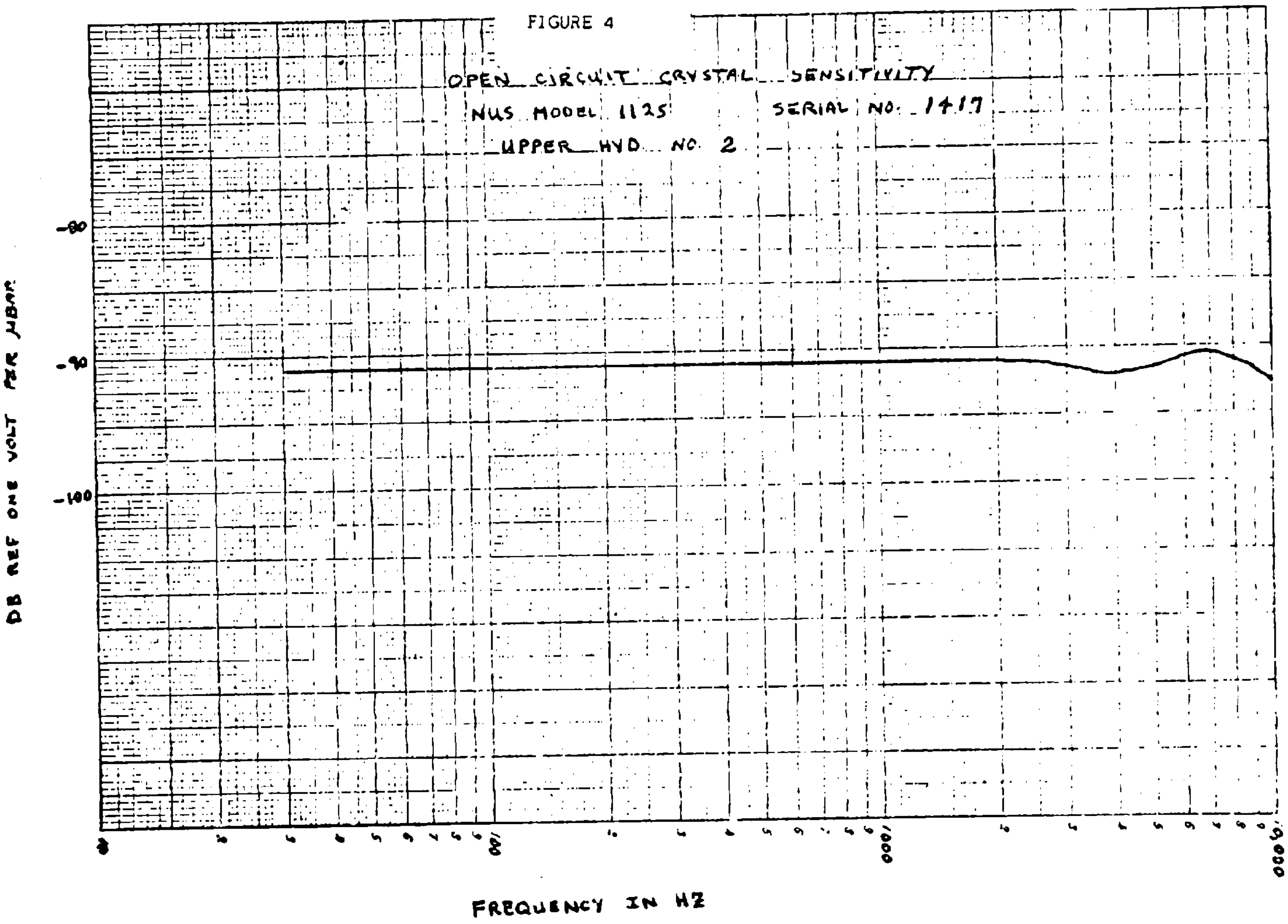

OPEN CIRCUIT CRYSTAL SENSITIVITY
NUS MODEL 1125
SERIAL NO. 1417
UPPER HYD NO. 2
-80
-90
-100
DB REF ONE VOLT PER μBAR
10
100
1000
10,000
FREQUENCY IN HZ

FIGURE 5

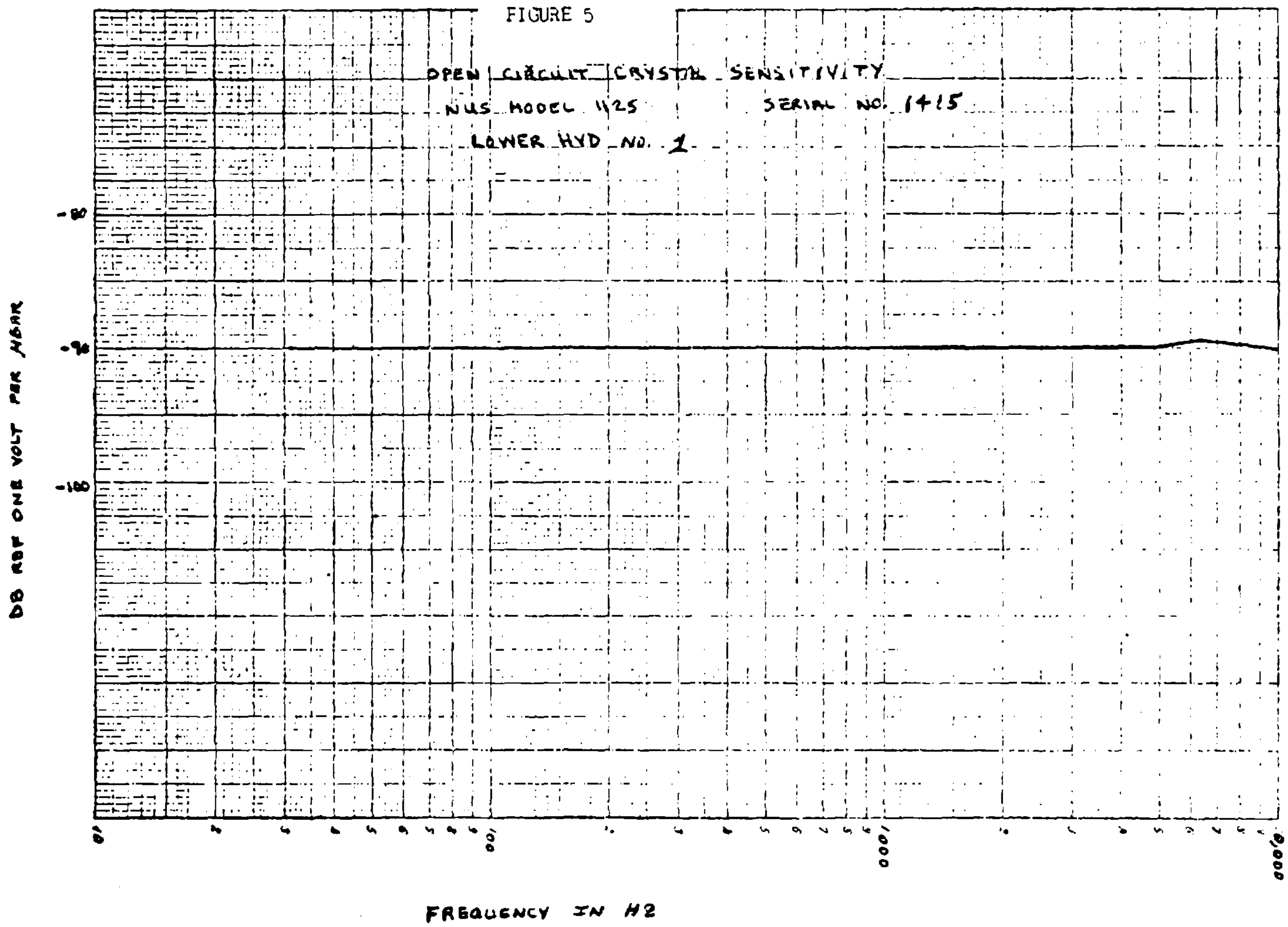
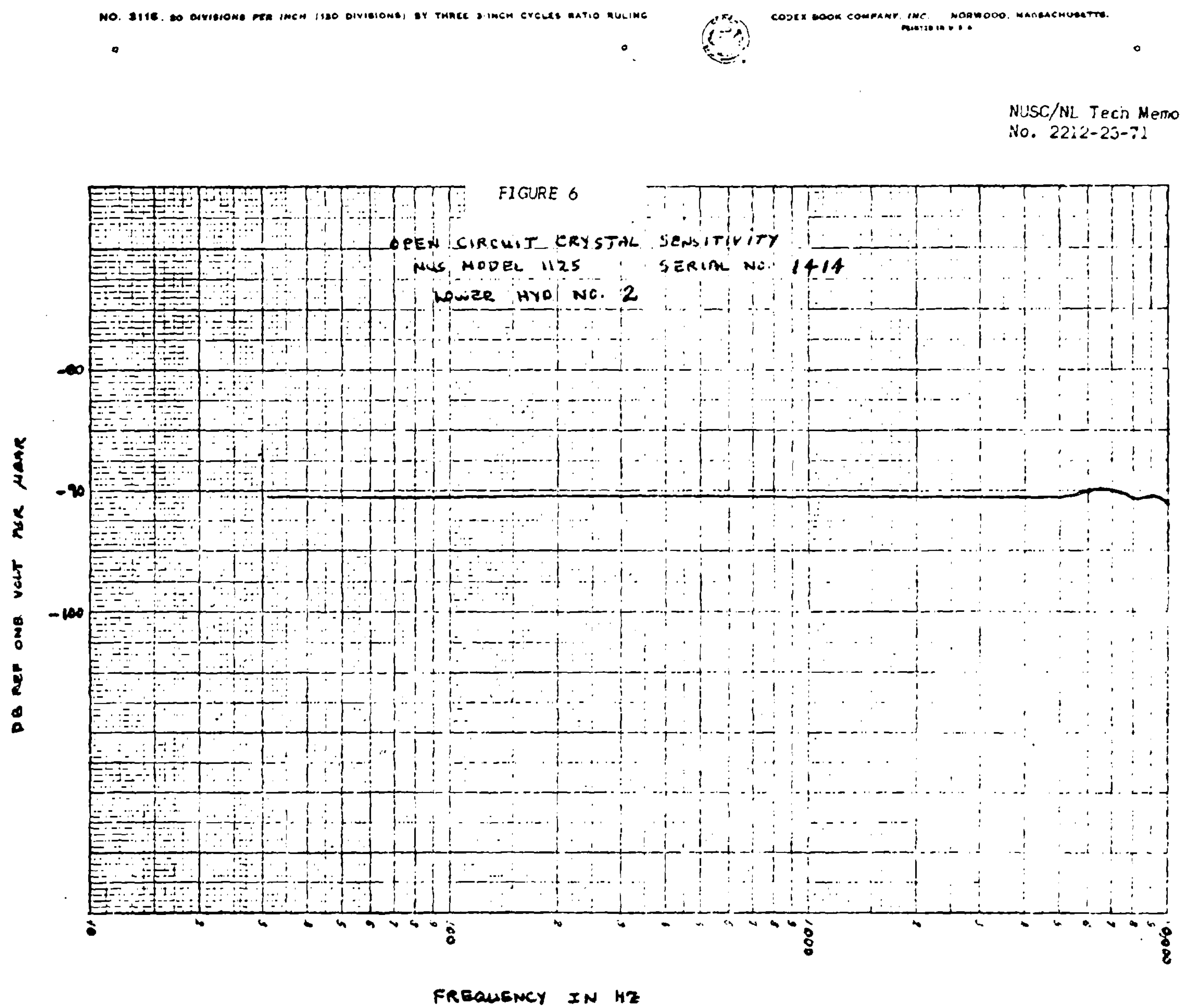

OPEN CIRCUIT CRYSTAL SENSITIVITY
NUS MODEL 1125
SERIAL NO. 1415
LOWER HYD NO. 1
-90
-96
-100
DB REF ONE VOLT PER μBAR
10
100
1000
10,000
FREQUENCY IN HZ

FIGURE 6


NO. 3116. 20 DIVISIONS PER INCH (120 DIVISIONS) BY THREE 3-INCH CYCLES RATIO RULING
CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS.
OPEN CIRCUIT CRYSTAL SENSITIVITY
NUS MODEL 1125 SERIAL NO. 1414
LOWER HYD NO. 2
-80
-90
-100
DB REF ONE VOLT PER μBAR
10
100
1000
10,000
FREQUENCY IN HZ

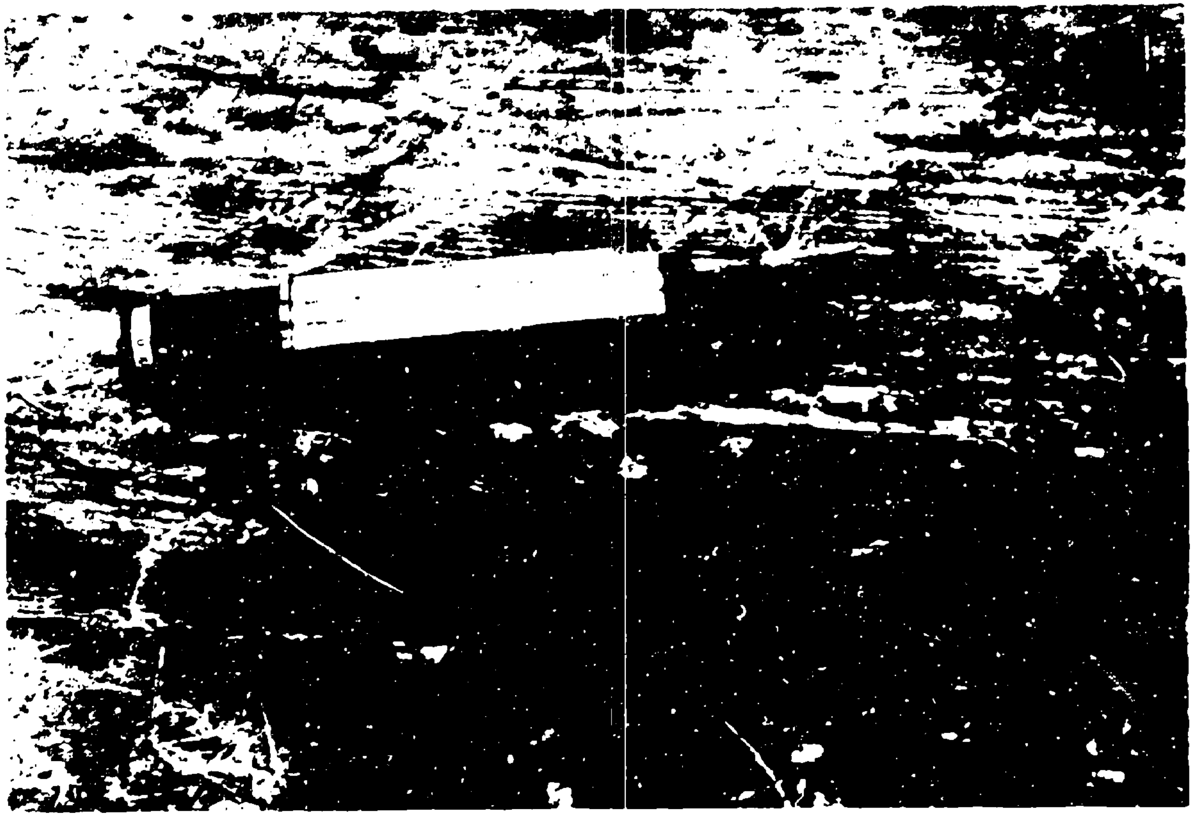


Fig. 7

NUSC, New London Laboratory
NP24 - 40151 - 1 - 71

Official Photograph

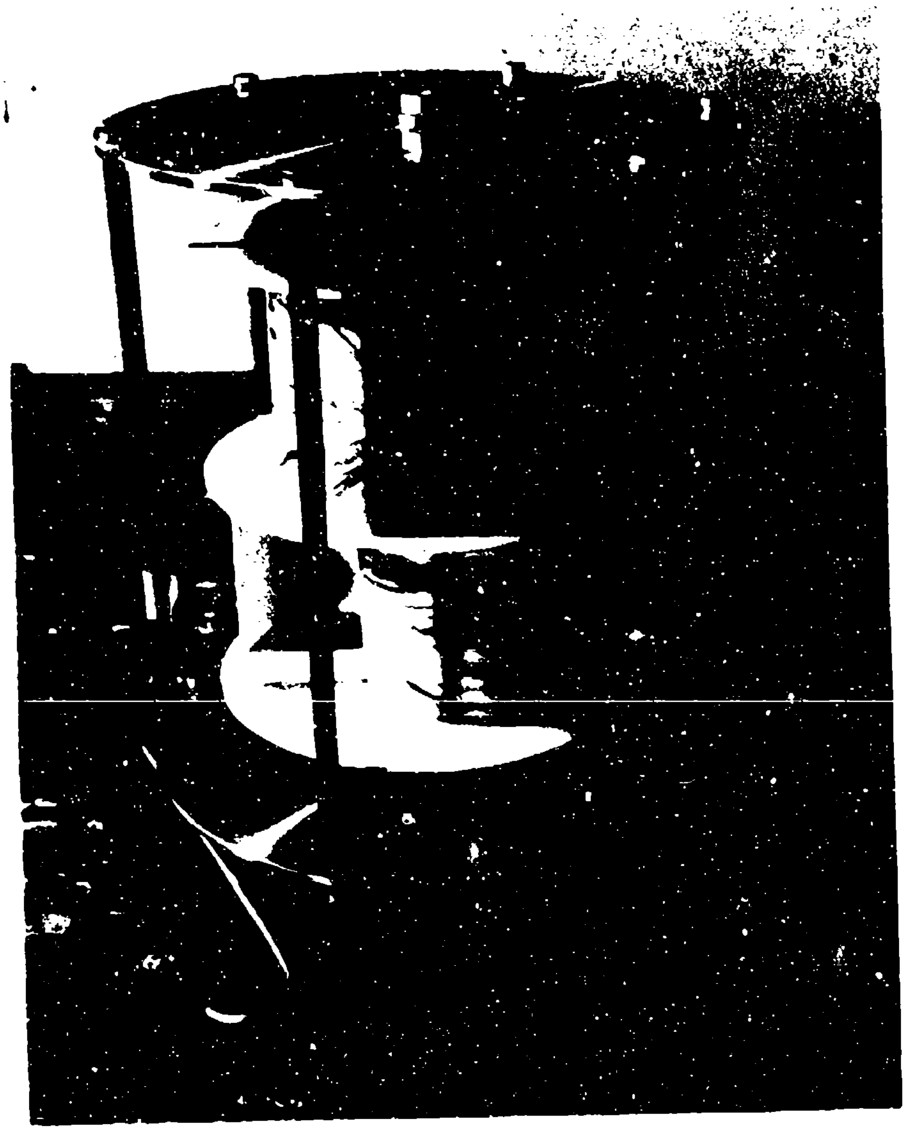


Fig. 8

NUSC/NL Tech Memo No. 2212-23-71

NUSC, New London Laboratory
NP24 - 40149 - 1 - 71

Official Photograph

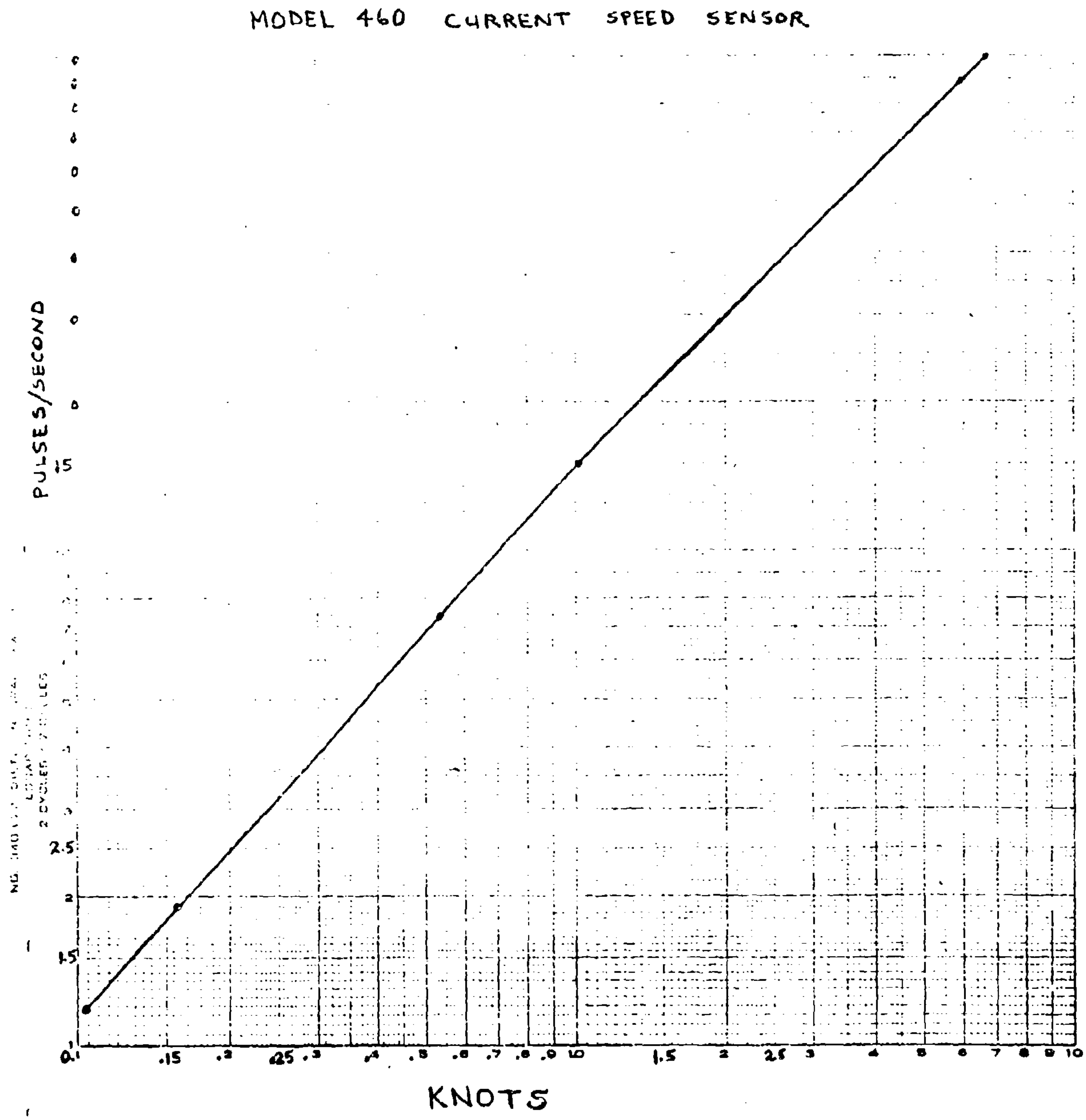

MODEL 460 CURRENT SPEED SENSOR
PULSES/SECOND
KNOTS
0.1
.15
.2
.25
.4
.5
.6
.7
.8
.9
1.0
1.5
2
2.5
3
4
5
6
7
8
9
10
1.5
2
2.5
15

FIGURE 8A

Fig. 9

NUSC/NL Tech Memo No. 2212-23-71

NUSC, New London Laboratory
NP24 - 40148 - 1 - 71

Official Photograph

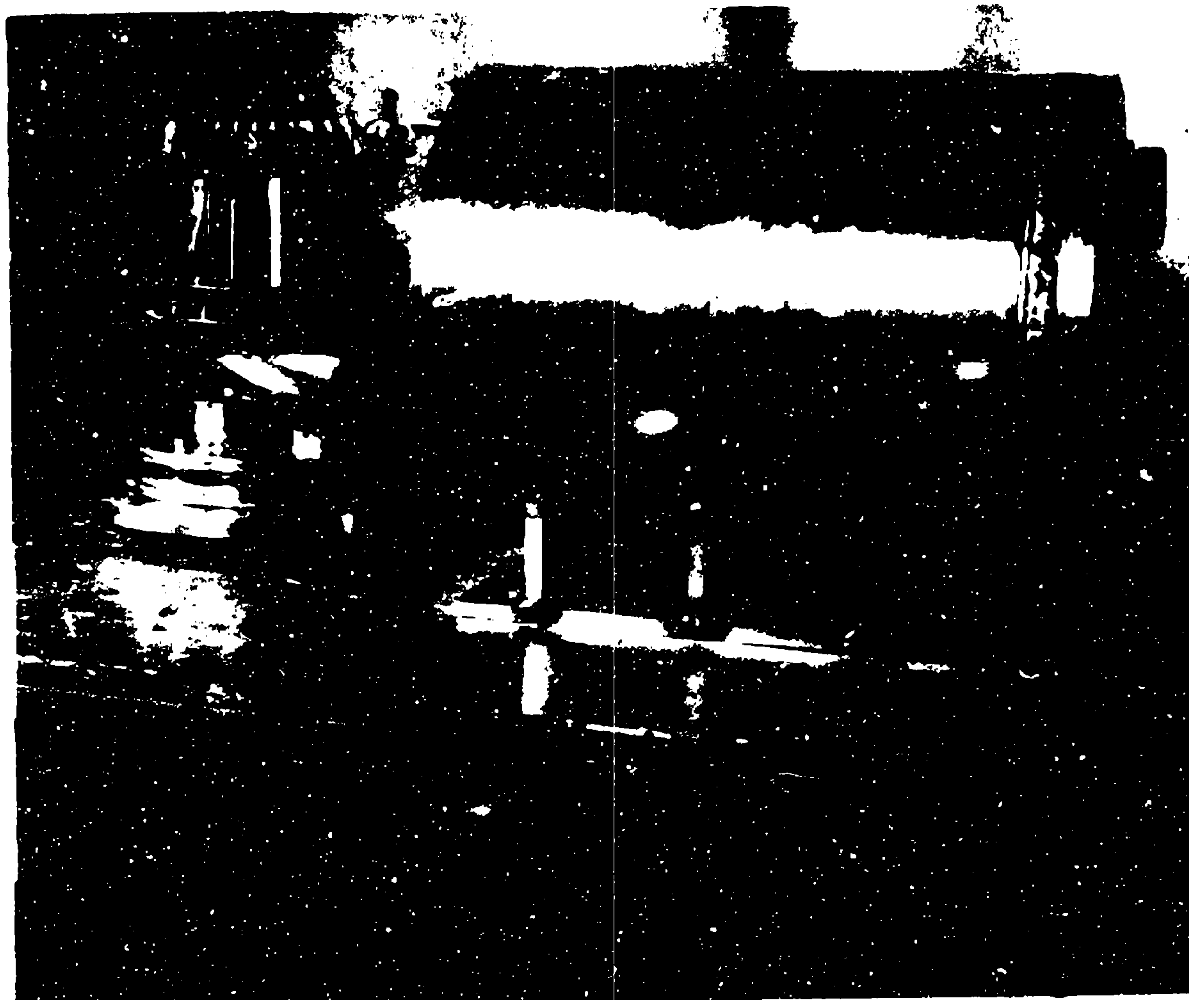


Fig. 10

NUSC/NL Tech Memo No. 2212-23-71

NUSC, New London Laboratory
NP24 - 40150 - 1 - 71

Official Photograph

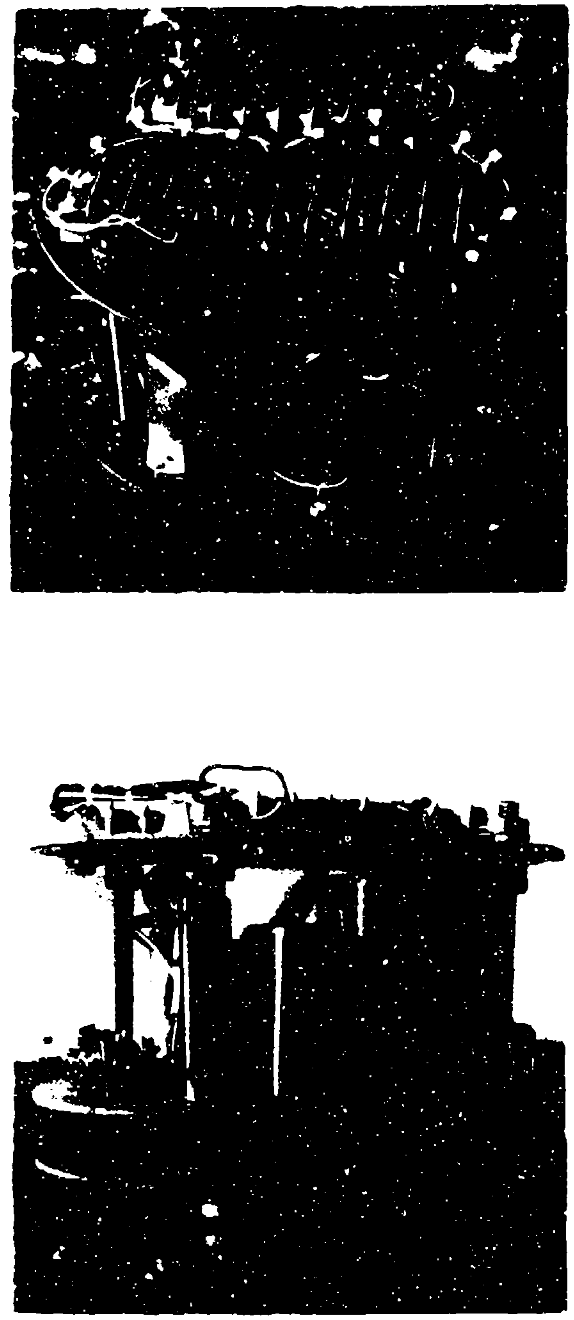


Fig. 11

NUSC/NL Tech Memo No. 2212-23-71

NUSC, New London Laboratory
NP24 - 40152 - 1 - 71

Official Photograph

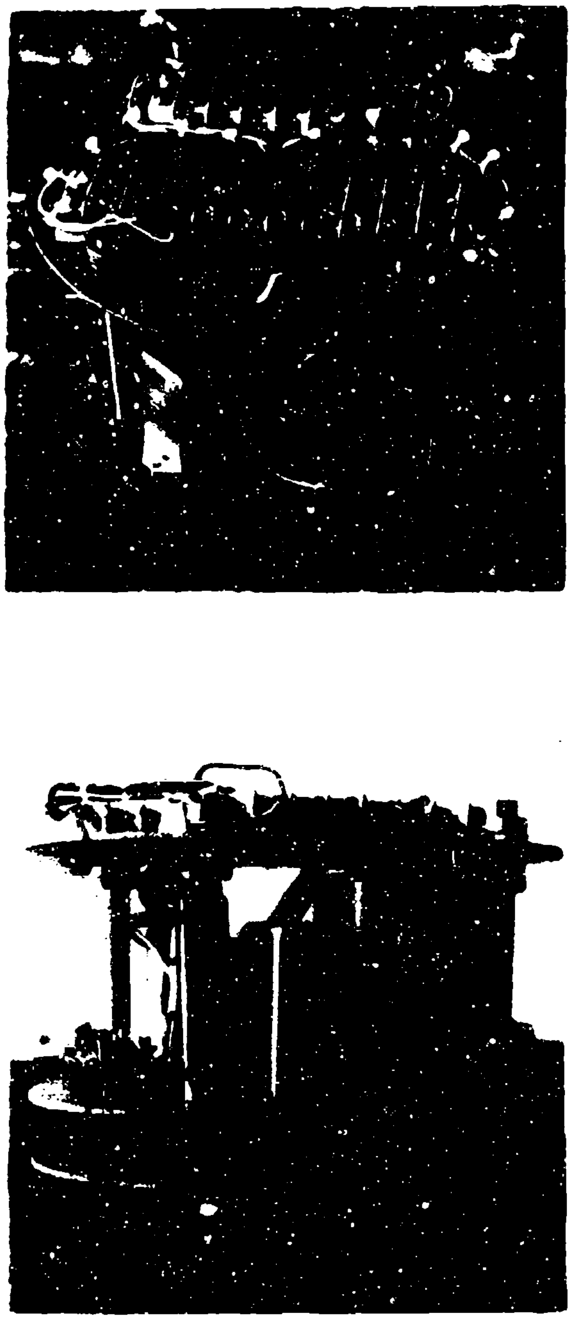


Fig. 11

NUSC/NL Tech Memo No. 2212-23-71

NUSC, New London Laboratory
NP24 - 40152 - 1 - 71

Official Photograph

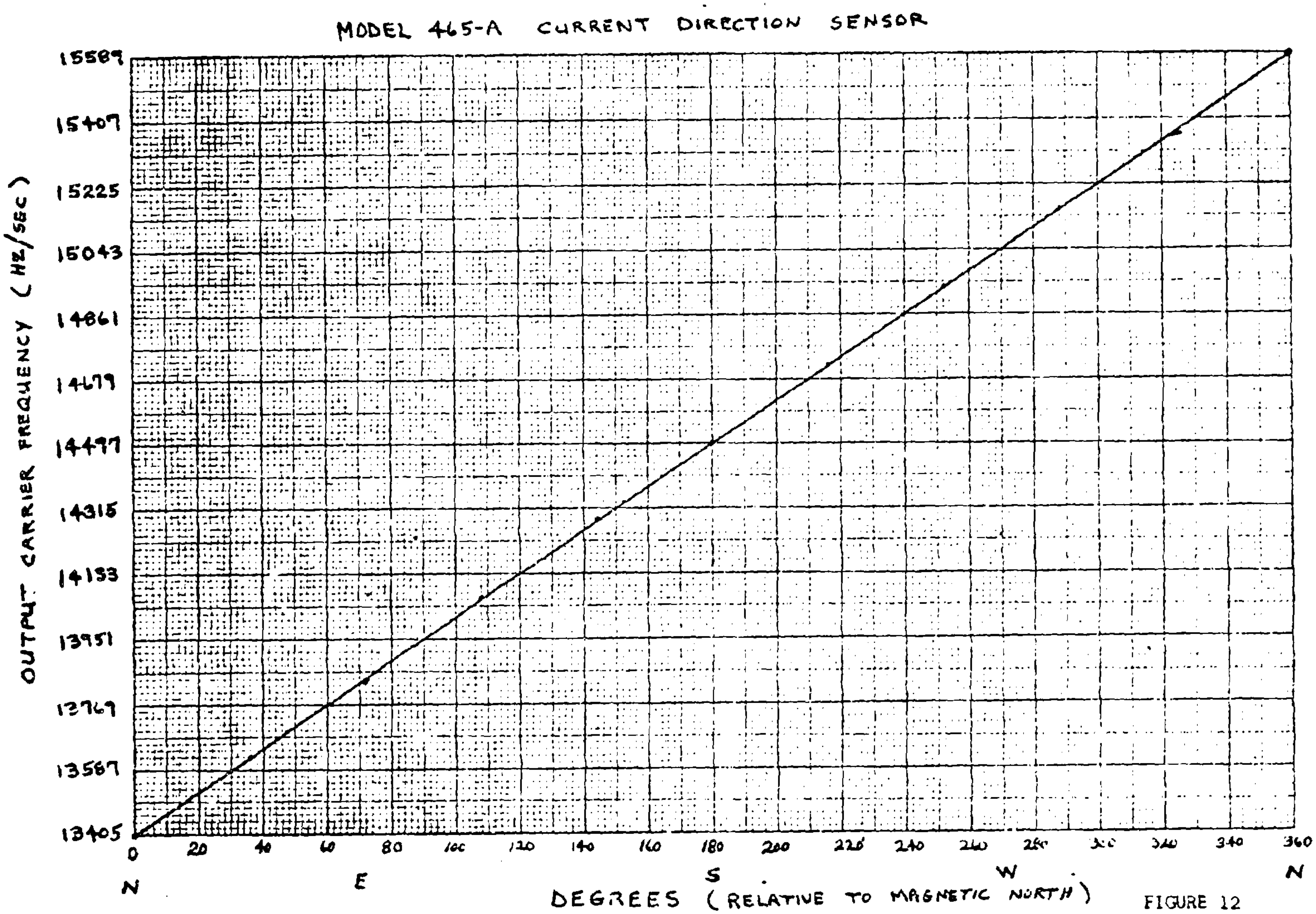

MODEL 465-A CURRENT DIRECTION SENSOR
OUTPUT CARRIER FREQUENCY (HZ/SEC)
15589
15407
15225
15043
14861
14679
14497
14315
14133
13951
13769
13587
13405
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
N E S W N
DEGREES (RELATIVE TO MAGNETIC NORTH)

FIGURE 12

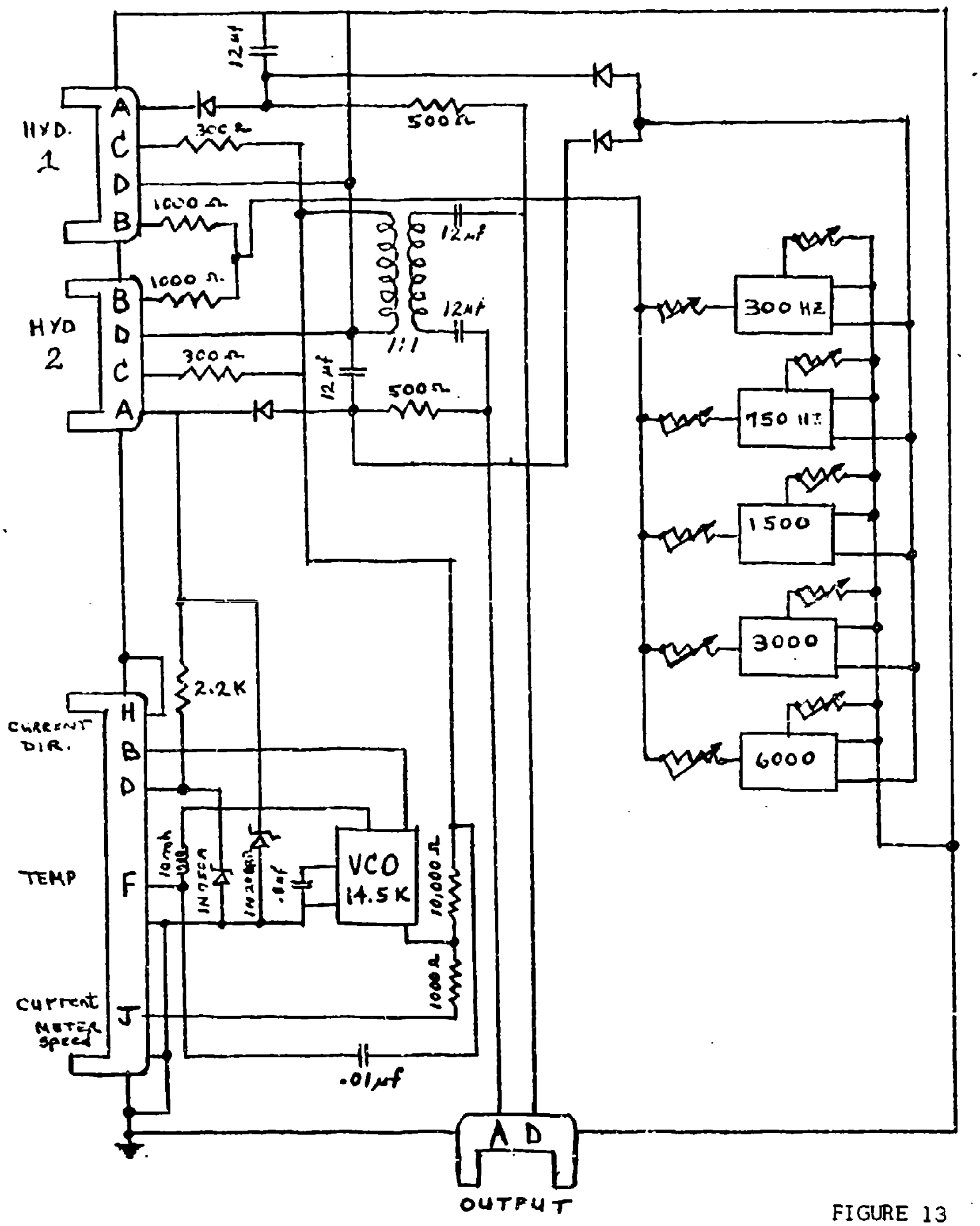


FIGURE 13

ELECTRONIC PACKAGE

TABLE 1

SHEET 1 of 6

NUSC/NL Tech Memo
No. 2212-23-71

lower temp. sensor

S O L T E N   I N D U S T R I E S

CALIBRATION TABLE FOR THERMOMETER MET-2 SN 27355 PAGE 3

deg °C

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	19539	19548	19556	19565	19574	19582	19591	19600	19609	19617
1.1	19626	19635	19643	19652	19661	19670	19678	19687	19696	[illegible]
1.2	19713	19722	19731	19739	19748	19757	19766	19774	19783	19792
1.3	19800	19809	19818	19827	19835	19844	19853	19862	19870	[illegible]
1.4	19888	19896	19905	19914	19923	19931	19940	19949	19958	[illegible]
1.5	19975	19984	19992	20001	20010	20019	20027	20036	20045	[illegible]
1.6	20062	20071	20080	20088	20097	20106	20115	20123	20132	[illegible]
1.7	20150	20158	20167	20176	20185	20193	20202	20211	20219	[illegible]
1.8	20237	20246	20254	20263	20272	20281	20289	20298	20307	[illegible]
1.9	20324	20333	20342	20350	20359	20368	20377	20385	20394	20403

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.0	20412	20420	20429	20438	20447	20455	20464	20473	20482	20490
2.1	20499	20508	20517	20525	20534	20543	20551	20560	20569	20578
2.2	20586	20595	20604	20613	20621	20630	20639	20648	20656	20665
2.3	20674	20683	20691	20700	20709	20718	20726	20735	20744	20753
2.4	20761	20770	20779	20788	20796	20805	20814	20823	20831	20840
2.5	20849	20858	20866	20875	20884	20893	20901	20910	20919	20928
2.6	20936	20945	20954	20963	20971	20980	20989	20998	21006	21015
2.7	21024	21033	21041	21050	21059	21068	21076	21085	21094	21103
2.8	21111	21120	21129	21138	21146	21155	21164	21173	21181	21190
2.9	21199	21208	21216	21225	21234	21243	21251	21260	21269	21278

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
3.0	21286	21295	21304	21313	21321	21330	21339	21348	21356	21365
3.1	21374	21383	21392	21400	21409	21418	21427	21435	21444	21453
3.2	21462	21470	21479	21488	21497	21505	21514	21523	21532	21540
3.3	21549	21558	21567	21576	21584	21593	21602	21611	21619	21628
3.4	21637	21646	21654	21663	21672	21681	21689	21698	21707	21716
3.5	21725	21733	21742	21751	21760	21768	21777	21786	21795	21803
3.6	21812	21821	21830	21839	21847	21856	21865	21874	21882	21891
3.7	21900	21909	21917	21926	21935	21944	21953	21961	21970	21979
3.8	21988	21996	22005	22014	22023	22032	22040	22049	22058	22067
3.9	22075	22084	22093	22102	22111	22119	22128	22137	22146	22154

TABLE 1

SHEET 2 of 6

lower temp sensor

G U L T O N I N D U S T R I E S

CALIBRATION TABLE FOR THERMOMETER MET-2 SN 27355

deg °C	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.0	22163	22172	22181	22190	22198	22207	22216	22225	22233	[illegible]
4.1	22251	22260	22269	22277	22286	22295	22304	22312	22321	[illegible]
4.2	22339	22348	22356	22365	22374	22383	22391	22400	22409	[illegible]
4.3	22427	22435	22444	22453	22462	22471	22479	22488	22497	[illegible]
4.4	22514	22523	22532	22541	22550	22558	22567	22576	22585	[illegible]
4.5	22602	22611	22620	22629	22637	22646	22655	22664	22673	[illegible]
4.6	22690	22699	22708	22717	22725	22734	22743	22752	22761	[illegible]
4.7	22778	22787	22796	22804	22813	22822	22831	22840	22848	22857
4.8	22866	22875	22884	22892	22901	22910	22919	22928	22936	22945
4.9	22954	22963	22972	22980	22989	22998	23007	23016	23024	23033

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
5.0	23042	23051	23060	23068	23077	23086	23095	23104	23112	23121
5.1	23130	23139	23148	23156	23165	23174	23183	23192	23200	23209
5.2	23218	23227	23236	23244	23253	23262	23271	23280	23288	23297
5.3	23306	23315	23324	23332	23341	23350	23359	23368	23376	23385
5.4	23394	23403	23412	23420	23429	23438	23447	23456	23464	23473
5.5	23482	23491	23500	23508	23517	23526	23535	23544	23553	23561
5.6	23570	23579	23588	23597	23605	23614	23623	23632	23641	23649
5.7	23658	23667	23676	23685	23693	23702	23711	23720	23729	23738
5.8	23746	23755	23764	23773	23782	23790	23799	23808	23817	23826
5.9	23835	23843	23852	23861	23870	23879	23887	23896	23905	23914

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
6.0	23923	23931	23940	23949	23958	23967	23976	23984	23993	24002
6.1	24011	24020	24029	24037	24046	24055	24064	24073	24081	24090
6.2	24099	24108	24117	24126	24134	24143	24152	24161	24170	24178
6.3	24187	24196	24205	24214	24223	24231	24240	24249	24258	24267
6.4	24276	24284	24293	24302	24311	24320	24328	24337	24346	24355
6.5	24364	24373	24381	24390	24399	24408	24417	24426	24434	24443
6.6	24452	24461	24470	24479	24487	24496	24505	24514	24523	24532
6.7	24540	24549	24558	24567	24576	24585	24593	24602	24611	24620
6.8	24629	24638	24646	24655	24664	24673	24682	24691	24699	24708
6.9	24717	24726	24735	24744	24752	24761	24770	24779	24788	24797

TABLE 1
SHEET 3 of 6

lower temp sensor

CALIBRATION TABLE FOR THERMOMETER MET-2 SN 27355 PAGE

deg °C	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
7.0	24805	24814	24823	24832	24841	24850	24858	24867	24876	[illegible]
7.1	24894	24903	24911	24920	24929	24938	24947	24956	24964	[illegible]
7.2	24982	24991	25000	25009	25018	25026	25035	25044	25053	[illegible]
7.3	25071	25079	25088	25097	25106	25115	25124	25132	25141	[illegible]
7.4	25159	25168	25177	25186	25194	25203	25212	25221	25230	[illegible]
7.5	25247	25256	25265	25274	25283	25292	25301	25309	25318	[illegible]
7.6	25336	25345	25354	25363	25371	25380	25389	25398	25407	[illegible]
7.7	25424	25433	25442	25451	25460	25469	25478	25486	25495	[illegible]
7.8	25513	25522	25531	25540	25548	25557	25566	25575	25584	25593
7.9	25602	25610	25619	25628	25637	25646	25655	25664	25672	[illegible]
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
8.0	25690	25699	25708	25717	25726	25734	25743	25752	25761	25770
8.1	25779	25788	25796	25805	25814	25823	25832	25841	25850	25858
8.2	25867	25876	25885	25894	25903	25912	25920	25929	25938	25947
8.3	25956	25965	25974	25982	25991	26000	26009	26018	26027	26036
8.4	26045	26053	26062	26071	26080	26089	26098	26107	26115	26124
8.5	26133	26142	26151	26160	26169	26177	26186	26195	26204	26213
8.6	26222	26231	26240	26248	26257	26266	26275	26284	26293	26302
8.7	26311	26319	26328	26337	26346	26355	26364	26373	26381	26390
8.8	26399	26408	26417	26426	26435	26444	26452	26461	26470	26479
8.9	26488	26497	26506	26515	26523	26532	26541	26550	26559	26568
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
9.0	26577	26586	26594	26603	26612	26621	26630	26639	26648	26657
9.1	26665	26674	26683	26692	26701	26710	26719	26728	26737	26745
9.2	26754	26763	26772	26781	26790	26799	26808	26816	26825	26834
9.3	26843	26852	26861	26870	26879	26888	26896	26905	26914	26923
9.4	26932	26941	26950	26959	26967	26976	26985	26994	27003	27012
9.5	27021	27030	27039	27047	27056	27065	27074	27083	27092	27101
9.6	27110	27119	27127	27136	27145	27154	27163	27172	27181	27190
9.7	27199	27207	27216	27225	27234	27243	27252	27261	27270	27279
9.8	27287	27296	27305	27314	27323	27332	27341	27350	27359	27367
9.9	27376	27385	27394	27403	27412	27421	27430	27439	27448	27456

TABLE 1

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NUSC/NL Tech Memo
No. 2212-23-71

upper temp sensor G U L T O N I N D U S T R I E S

CALIBRATION TABLE FOR THERMOMETER MET-2 S N 27356 PAGE 3

°C	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	20134	20143	20152	20160	20169	20178	20187	20195	20204	20213
1.1	20221	20230	20239	20247	20256	20265	20273	20282	20291	20300
1.2	20308	20317	20326	20334	20343	20352	20360	20369	20378	20387
1.3	20395	20404	20413	20421	20430	20439	20448	20456	20465	20474
1.4	20482	20491	20500	20508	20517	20526	20535	20543	20552	20561
1.5	20569	20578	20587	20595	20604	20613	20622	20630	20639	20648
1.6	20656	20665	20674	20683	20591	20700	20709	20717	20726	20735
1.7	20744	20752	20761	20770	20778	20787	20796	20804	20813	20822
1.8	20831	20839	20848	20857	20865	20874	20883	20892	20900	20909
1.9	20918	20926	20935	20944	20953	20961	20970	20979	20987	20996

°C	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.0	21005	21014	21022	21031	21040	21048	21057	21066	21075	[illegible]
2.1	21092	21101	21109	21118	21127	21136	21144	21153	21162	21170
2.2	21179	21188	21197	21205	21214	21223	21231	21240	21249	[illegible]
2.3	21266	21275	21284	21292	21301	21310	21319	21327	21336	21345
2.4	21353	21362	21371	21380	21388	21397	21406	21414	21423	[illegible]
2.5	21441	21449	21458	21467	21475	21484	21493	21502	21510	21519
2.6	21528	21537	21545	21554	21563	21571	21580	21589	21598	[illegible]
2.7	21615	21624	21632	21641	21650	21659	21667	21676	21685	21694
2.8	21702	21711	21720	21728	21737	21746	21755	21763	21772	21781
2.9	21789	21798	21807	21816	21824	21833	21842	21851	21859	[illegible]

°C	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
3.0	21877	21885	21894	21903	21912	21920	21929	21938	21947	[illegible]
3.1	21964	21973	21981	21990	21999	22008	22016	22025	22034	[illegible]
3.2	22051	22060	22069	22077	22086	22095	22104	22112	22121	22130
3.3	22139	22147	22156	22165	22174	22182	22191	22200	22208	22217
3.4	22226	22235	22243	22252	22261	22270	22278	22287	22296	[illegible]
3.5	22313	22322	22331	22339	[illegible]	[illegible]	[illegible]	22374	[illegible]	[illegible]
3.6	22401	22409	22418	22427	[illegible]	22444	[illegible]	[illegible]	[illegible]	[illegible]
3.7	22488	22497	22505	22514	22523	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.8	22575	22584	22593	22602	22610	22619	22625	22637	[illegible]	22654
3.9	22663	22671	22680	22689	22698	22706	22715	22724	22733	22741

TABLE 1

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upper temp sensor

CALIBRATION TABLE FOR THERMOMETER [illegible]

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.0	22750	22759	22768	22776	22785	22794	22603	22811	22820	22829
4.1	22838	22845	22855	22864	22873	22881	22890	22899	22907	22916
4.2	22925	22934	22942	22951	22960	22969	22977	22986	22995	[illegible]
4.3	23012	23021	23030	23039	23047	23056	23065	23074	23082	23091
4.4	23100	23109	23117	23126	23135	23144	23152	23161	23170	23179
4.5	23187	23196	23205	23214	23222	23231	23240	23249	23257	23266
4.6	23275	23284	23292	23301	23310	23319	23327	23336	23345	23354
4.7	23362	23371	23380	23389	23397	23406	23415	23424	23432	23441
4.8	23450	23459	23467	23476	23485	23494	23502	23511	[illegible]	23529
4.9	23537	23546	23555	23564	23572	23581	23590	23599	[illegible]	[illegible]

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
5.0	23625	23634	23642	23651	23660	23669	23677	23686	23695	23704
5.1	23713	23721	23730	23739	23748	23756	23765	23774	23783	23791
5.2	23800	23809	23818	23826	23835	23844	23853	23861	23870	23879
5.3	23888	23896	23905	23914	23923	23931	23940	23949	23958	23967
5.4	23975	23984	23993	24002	24010	24019	24028	24037	24045	24054
5.5	24063	24072	24080	24089	24098	24107	24115	24124	24133	24142
5.6	24151	24159	24168	24177	24186	24194	24203	24212	24221	24229
5.7	24238	24247	24256	24264	24273	24282	24291	24300	24308	24317
5.8	24326	24335	24343	24352	24361	24370	24378	24387	24396	24405
5.9	24414	24422	24431	24440	24449	24457	24466	24475	24484	24492

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
6.0	24501	24510	24519	24528	24536	24545	24554	24563	24571	24580
6.1	24589	24598	24606	24615	24624	24633	24642	24650	24659	24668
6.2	24677	24685	24694	24703	24712	24721	24729	24738	24747	24756
6.3	24764	24773	24782	24791	24800	24808	24817	24826	24835	24843
6.4	24852	24861	24870	24878	24887	24896	24905	24914	24922	24931
6.5	24940	24949	24957	24966	24975	24984	24993	25001	25010	25019
6.6	25028	25036	25045	25054	25063	25072	25080	25089	25098	25107
6.7	25116	25124	25133	25142	25151	25159	25168	25177	25186	25195
6.8	25203	25212	25221	25230	25238	25247	25256	25265	25274	25282
6.9	25291	25300	25309	25318	25326	25335	25344	25353	25361	25370

TABLE 1

SHEET 6 of 6

upper temp sensor

SULTON INDUSTRIES

CALIBRATION TABLE FOR THERMOMETER YST-2 S/N 27356

deg °C	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
7.0	25379	25388	25397	25405	25414	25423	25432	25441	25449	25458
7.1	25467	25476	25484	25493	25502	25511	25520	25528	25537	25546
7.2	25555	25564	25572	25581	25590	25599	25607	25616	25625	[illegible]
7.3	[illegible]	25651	25660	25669	25676	25687	25695	25704	25713	25722
7.4	25731	25739	25748	25757	25765	25774	25783	25792	25801	25810
7.5	25818	25827	25836	25845	25854	25867	25871	25880	25889	25898
7.6	25906	25915	25924	25933	25942	25950	25959	25968	25977	25986
7.7	25994	26003	26012	26021	26030	26038	26047	[illegible]	[illegible]	26074
7.8	26082	26091	26100	26109	26117	26126	26135	26144	[illegible]	26161
7.9	26170	26179	26188	26197	26205	26214	26223	26232	26241	26249
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
8.0	26258	26267	26276	26285	26293	26302	26311	26320	[illegible]	26337
8.1	26346	26355	26364	26373	26382	26390	26399	26408	26417	26426
8.2	26434	26443	26452	26461	26470	26478	26487	26496	26505	26514
8.3	26522	26531	26540	26549	26558	26566	26575	26584	26593	26602
8.4	26610	26619	26628	26637	26646	26654	26663	26672	26681	26690
8.5	26698	26707	26716	26725	26734	26743	26751	26760	26769	26778
8.6	26787	26795	26804	26813	26822	26831	26839	26848	26857	26866
8.7	26875	26884	26892	26901	26910	26919	26928	26936	26945	26954
8.8	26963	26972	26980	26989	26998	27007	27016	27025	27033	27042
8.9	27051	27060	27069	27077	27086	27095	27104	27113	27121	27130
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
9.0	27139	27148	27157	27166	27174	27183	27192	27201	27210	27218
9.1	27227	27236	27245	27254	27263	27271	27280	27289	27298	27307
9.2	27315	27326	27333	27342	27351	27360	27368	27377	27386	27395
9.3	27404	27412	27421	27430	27439	27448	27457	27465	27474	27483
9.4	27492	27501	27510	27518	27527	27536	27545	27554	27562	27571
9.5	27580	27589	27598	27607	27615	27624	27633	27642	27651	27660
9.6	27668	27677	27686	27695	27704	27712	27721	27730	27739	27748
9.7	27757	27765	27774	27783	27792	27801	27810	27818	27827	27836
9.8	27845	27854	27863	27871	27880	27889	27898	27907	27916	27924
9.9	27933	27942	27951	27960	27969	27977	27986	27995	28004	28013

TABLE II

UPPER ASSEMBLY

Unit Type	Manufacturer	Serial#	Model#	Utilization
Hydrophone 1	NUS Corporation	1419	1125	Mode 1
Hydrophone 2	NUS Corporation	1417	1125	Mode 2
Temperature Probe	Gulton Industries	27356	MET-2	Mode 2
Current Speed Sensor	Hydro Products	659949	460	Mode 2
Current Direction Sensor	Hydrc Products	659834	465-A	Mode 2

LOWER ASSEMBLY

Unit Type	Manufacturer	Serial#	Model#	Utilization
Hydrophone 1	NUS Corporation	1415	1125	Mode 1
Hydrophone 2	NUS Corporation	1414	1125	Mode 2
Temperature Probe	Gulton Industries	27355	MET-2	Mode 2
Current Speed Sensor	Hydro Products	658949	460	Mode 2
Current Direction Sensor	Hydro Products	659948	465-A	Mode 2